Fall 2019

Processing Speed for Action and Semantic Memory

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PROCESSING SPEED FOR ACTION AND SEMANTIC MEMORY

by

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A Thesis
Submitted to the Graduate School,
the College of Education and Human Sciences
and the School of Psychology
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Arts

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December 2019

Published by the Graduate School

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ABSTRACT

Previous research suggests that the processing of affordances may require more perceptually relevant information than words can provide (Surber et al., 2018; Chainay & Humphreys, 2002). The present study investigates this hypothesis with the shoebox task used in Bowers and Turner (2003). A list of 81 object nouns (targets) and associated features (primes: affordance, semantic, and non-associates) was compiled from the McRae, Cree, Seidenberg, and McNorgan (2005) norms. Affordances denote possibilities for action in relation to the object (e.g. chair – sit), whereas semantic features indicate definitional characteristics (e.g. chair – has legs). Affordances and semantic features served as primes in the present experiments. Primes were presented as words in all experiments. Participants decided if primes and targets could fit inside of a shoebox across three experiments. Experiment 1 presented target objects as words (i.e. the name of the object) or photographs (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010). Experiment 2 presented target objects as photographs degraded by 1 of 3 levels (clear, medium blur, maximum blur). Experiment 3 presented target objects as photographs that began degraded and slowly became clear. Results for Experiments 1 and 2 showed a significant priming effect for affordances (i.e. affordance primed objects were responded to faster than objects primed with non-associate, as well as a significant effect of accuracy for affordance primed objects. Experiment 3 results showed a marginally significant effect of prime type on reaction time. These results are consistent with the idea that affordance perception is optimized for real-world stimuli.

ACKNOWLEDGMENTS

I would like to acknowledge my Mentor Dr. Alen Hajnal, for his guidance and support. Additionally, I would like to thank my committee members Dr. Mark Huff and Dr. Richard Mohn for their contributions to this paper. Finally, I would like to thank the members of the PAC lab, Mary Brown, Joseph Clark, Catherine Dowell, Johnathan Doyon, and Hannah Masoner, for their input and assistance while completing this project.

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CHAPTER I - Introduction

Interacting with an object in the environment is achieved by perceiving possibilities for action (i.e., affordances, Gibson, 2014). Our actions are mediated by an actor's capabilities and the environmental constraints imposed on the actor. Gibson argued that this process involves the pickup of meaningful information from the environment. Through repeated interactions with various objects and environments, an actor will begin to store a record of these interactions. This process helps the actor learn and form memories about their environment. Semantic memory, the storehouse of knowledge for what a person knows about the world (Balota & Coane, 2008), plays a crucial role in this process. This knowledge is gathered throughout one's life, and includes facts about the world, the meaning of words, one's ideas, and the concept of objects. Given affordances are essential for everyday functioning and behavior, affordance features should be distinct from, and perhaps even more salient than, semantic features of objects.

Supporting the claim that affordance features are processed differently from semantic features, recent research has shown that there may be a separate memory process for action features (Silveri & Ciccarelli, 2009). Research on patients with brain impairments has shown that patients can use an object without having semantic knowledge of the object (Hodges, Bozeat, Ralph, Patterson, & Spatt, 2000; Silveri & Ciccarelli, 2009). Silveri and Ciccarelli (2009) investigated whether patients with mild to severe semantic memory impairment were able to recognize and/or use objects. The authors concluded that when semantic memory deficits are mild, non-declarative forms of memory such as procedural-motor memory can support and compensate the patient's ability to act. However, it is important to note that semantic memory and procedural-motor memory interact. This can be seen in patients with severe neurological deficits, as they are unable to complete tasks that involve functional use of objects.

1.1 Theories of Semantic Processing

In order to investigate the potential differences between affordance features and semantic features, I need to first review the literature on theories of semantic processing. The network approach was developed by Quillian (1968), and further improved upon by Collins and Loftus (1975). The main feature of this approach is that semantic knowledge is embedded within a network structure and is linked by association. This model posits that related concepts are organized closer together in the network than unrelated concepts. The alternative approach called the Feature Analytic Theory developed by Smith, Shoben, and Rips (1974) focuses on defining and characteristic features. Defining features are the necessary features of exemplars or prototypes of a category, whereas characteristic features are shared features of most exemplars. It is still unclear what is the nature of these representations, and how they are formed. Regardless, there might be some evidence for using the sensorimotor system as a grounding for semantic memory representations.

Barsalou (1999) posited a link between sensorimotor systems and semantic memory with his theory of Perceptual Symbol Systems. According to Barsalou (1999) information is picked up from the environment via several different modalities and processing systems: The sensory system (i.e., sight, haptic), the motor system (i.e., actions), kinesthetic system (i.e., object manipulation), proprioceptive systems (i.e., internal feedback system), emotional systems (i.e., happy, fear), the cognitive systems (i.e., language processing), and the perceptual system (i.e., affordance processing). The information gathered from modalities is processed in their respective memory system (i.e., visual memory). The information is then integrated together in association areas. Retrieving from semantic memory involves a simulator, in which neural activation at encoding becomes reinstated.

Siakaluk, Pexman, Aguilera, Owen, and Sears (2008a) used perceptual symbol systems as the theoretical model for a word recognition task. In their experiment, body-object interaction (BOI), the ease with which someone could physically interact with the referent of the word, was used as the measure of sensorimotor knowledge. Participants engaged in a Lexical Decision Task (LDT) comparing high BOI words with low BOI words. They found a facilitatory effect of BOI with high BOI words being recognized faster than low BOI words. The authors explained this using the feedback activation framework of visual word recognition (Hino & Lupker, 1996). The high BOI words had richer semantic representations which provided stronger feedback activation to orthography and phonology, facilitating reaction times. It is therefore possible that affordances may have high BOI value due to rich action-related content and which in turn would be processed faster than low BOI words.

Siakaluk et al. (2008b) followed up their experiment by looking at BOI and direct semantic processing. Experiment 1A and 1B consisted of a semantic categorization task (SCT) in which participants decided whether words were easily imageable (1A) or not easily imageable (1B). Imageability was defined as the ease with which a word can produce a mental image. Across experiments reaction times and accuracy were greater for high BOI versus low BOI words. Experiment 2 involved a semantic lexical decision task (SLDT) where participants first made a lexical decision followed by an imageability response. Again, BOI effects were detected and these were even larger than Experiment 1, further supporting the notion that high BOI can promote semantic processing.

In a subsequent study, Wellsby, Siakaluk, Owen, and Pexman (2011) evaluated the possibility that BOI facilitation was due to the motor system speeding key presses versus semantic activation. To test this priming hypothesis, the authors used three go/no-go semantic categorization tasks: A button press condition, a pronunciation condition, and a verbal condition, and participants were asked to respond to words that were imageable. Across tasks, the BOI facilitation effect was found, providing evidence for embodied cognition and against the motor priming hypothesis.

1.2 Affordances and Semantic Processing

Gibson (1979) theorized that all the sense organs can pick up the same information from the environment using different forms of stimulus energy. This suggests that if a sensory organ is relevant for a given behavior, it will perceive some form of environmental information to aid in the actualization of the affordance. By picking up this information an actor can perform successful actions within their environment. Each animal forms a unique relationship with the environment due to different intrinsic metrics (i.e., eye height, strength, motor functioning, etc.) relevant to only that specific animal and task. In this way, a unique link is established between actor and environment. Perceptual systems are suited to perceive relational properties (animal-environment relationship) that fulfill meaningful actions. This animal-environment relationship implies that the animal must be aware of its own capabilities, as well as the environment and its features to accurately perceive what it can do in a given situation. At the center of the relationship between the environment and the actor are the sensory and perceptual systems. This leads to one important implication, that perception and cognition function to process affordances and guide actions (Wilson 2002).

There are several affordance tasks that have been used by researchers. Wagman, Thomas, McBride and Day (2013) had participants make maximum reaching height judgements with or without the aid of objects (a stick and a stepstool). Participants made these decisions when objects were both present and absent from their view. For absent objects participants had to rely on their memory of the object while making their decisions. They found that participants were able to make accurate judgements of their reaching ability regardless of whether the object was present or absent. The authors concluded that this is due to the nature of affordance perception and memory according to the ecological perspective. Specifically, that perception and memory are not wholly distinct. These processes have a nested structure that act together to guide behaviors, and the two processes are best thought of as lying on two ends of the same continuous spectrum belonging to the same cognitive process.

Thomas and Riley (2014) expanded upon these results in two experiments. Experiment 1 replicated the results from Wagman et al. (2013), showing that participants were able to make accurate reaching judgements regardless of whether the stick was present or absent. Experiment 2 asked participants to make aperture pass-through-ability judgements (i.e., the minimum distance between two surfaces that afford passing through) while holding a stick. The stick was held in their right hand perpendicular to their body, making it harder to pass through smaller apertures. Participants were also asked to estimate the length of the stick used for reaching. The results again show that participants can make accurate affordance judgements regardless of whether participants were able to view the aid object (stick) or whether they had to remember its affordances. Further analysis compared affordance judgements with a lower-order metric judgement computed by combining perceived stick length with perceived abilities without aid. They found that participants' judgements were more accurate when participants were making action relevant decisions compared to action neutral decisions (i.e., stick length). The authors concluded that I perceive and interpret our environment based on action relevant criteria instead of lower-order properties such as metric length. This is evidence that affordance may be the most meaningful feature of an object compared to other semantic features.

Thomas and Riley (2015) manipulated action neutral properties of objects and had participants make decisions of maximum reachability. Specifically, they manipulated the mass and rotational inertia of two different rods, of the same length, used to aid in reachability. Participants made reachability judgements with both rods. Once participants had made their reaching judgements (with and without aid), participants were asked to report the heaviness of the two rods. This was done to determine if participants would remember action-neutral properties not relevant to the given task. Participants reported no differences in the affordance judgements between rods, which is not surprising given that both rods were the same length. This was true even when rods were absent from view and participants were required to remember affordance properties of the rod. The rod length judgements showed no difference in their reported weights. This is further evidence that perception and possibly memory, focuses on the action-relevant properties of objects that aid actions.

Another important cognitive process alongside memory is categorization. It is an open question whether categorization is based on affordance properties of objects, tools and tasks. There is empirical evidence showing that I categorize the surrounding environment through affordances available within the space. For instance, Greene, Baldassano, Esteva, Beck, and Fei-Fei (2014) presented participants with a scene (i.e., kitchen), and then asked which of 3 comparison scenes had the most in common with the target room. For example, if participants are shown a picture of a modern-day kitchen scene and asked which of three scenes (kitchen supply store, modern day laundry, medieval kitchen) is most similar to the presented pictures. The authors found that affordance-based similarities predicted which selection was most likely to be chosen by participants. What this means is that if any of the three scenes shared any functions with the presented scene, it was most likely to be selected over the others. This was compared to more traditional explanations of visual scene categorization such as visual features and objects. The authors concluded that this provides evidence for scene categorization based on affordances, which is another example of the perceptual systems interacting with semantic memory.

Pilot research conducted by Surber, Huff, Brown, Doyon, Clark, and Hajnal (2018) found affordance primes to be slower than semantic features and non-associates in a reaction time task that used words as stimuli presented on a computer screen when asked to judge whether the meaning of the word is abstract or concrete. One possibility for the inferior performance of affordance primes might be the fact that affordances are typically encountered through our senses, and not linguistically. Consistent with this notion, Snow, Skiba, Coleman, and Berryhill (2014) found that participants were able to remember more real-world objects compared to pictures of the same objects.

Similarly, Chainay and Humphreys (2002) found that action knowledge is more relevant for pictures of objects compared with the name of the object. Participants were presented with objects as either pictures (line drawings) or words (name of object), and asked to perform one of two tasks (semantic categorization or action decision). Participants in the semantic categorization task were asked to decide if the object could commonly be found in a kitchen, while the instructions for the action decision task were to decide if the object was twistable or pourable. The authors found that participants were faster and more accurate for objects presented as pictures when the task was action oriented, while objects presented as words facilitated responding to the semantic task.

To sum up, sensory information (pictures over words) is more relevant to action than to higher level cognition, and direct sensory information (seeing a real object) is processed faster than indirect sensory information (looking at photographs of objects).

1.3 Overview of the Current Study

For the present experiment, I hypothesized that visual information may be needed to facilitate the priming effects of affordances. Specifically, pictorial depictions of objects might be better suited for facilitating affordance-based priming than linguistic information such as reading a word on a computer screen. To test these hypotheses, I investigated the effects of priming (affordances, feature, or non-associate) on a semantic categorization task. In Experiment 1, a set of 81 object (target) and prime pairs were used as stimuli. Photographs of the objects were obtained from the Bank of Standardized Stimuli (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010). Participants were assigned to either word or picture target conditions. Participants were presented with word primes followed by a target stimulus (word or picture). They were asked to decide if the stimuli (primes and targets) could fit inside of a shoebox (Bowers and Turner, 2003). The shoebox task gives two advantages versus the abstract/concrete task used in Surber et al. (2018). First, because pictures are inherently concrete, this could provide an advantage for affordance processing over words in the abstract/concrete categorization task. Secondly, the shoebox task is more ecologically valid for testing affordances than abstract/concrete decisions because the shoebox task asks participants to make an action decision. In Experiment 2, the same 81 images from Experiment 1 were used. Participants were presented with a prime and then a visual image (target). Participants were again asked to decide if the presented stimuli could fit inside a shoebox. To determine how much visual information is needed to facilitate responding to various types of primes, pictures were manipulated so that some images appeared clear, slightly blurry, or very blurry. To further investigate how much information is needed to recognize an object was examined in Experiment 3. I wanted to discover what is the minimum amount of visual information that is necessary to recognize an object, and whether less information is needed to process affordances than semantic content. Participants were first presented with a prime word (affordance, semantic feature, or non-associate). They were then presented with an artificially darkened screen so that features of the object were not visible initially, but then gradually became clearer. Participants were asked to identify the object as quickly as possible as the picture was becoming clearer. In sum, I argued that 1) affordances are optimally processed via perceptual information, not linguistically, 2) the quality of the perceptual information influences processing of affordances, and 3) visual object recognition is faster and more efficient when primed with affordance features compared to semantic features.

CHAPTER II – Experiment 1

2.1 Participants

58 participants (36 females; Mage=20.44 years) from the University of Southern Mississippi participated for partial course credit. Participants were required to have normal or corrected-to-normal vision and have no motor problems. A total of 62 participants were gathered for this experiment, but 4 participants had to be excluded due to English not being their first language.

2.2 Materials

Participants viewed the stimuli on a 30-inch color screen connected to a Windows 10 laptop. Responses (button presses) were made on a CMSTORM quick fire rapid mechanical gaming keyboard. Answers were given by pressing the 'F' key for 'Yes' and the 'J' key for 'No'. The stimuli were presented and button presses (response time) were controlled by E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA). A black cardboard shoebox was always visible to participants. The shoebox dimensions were length 30cm × width 23cm × height 13cm.

2.3 Design

Experiment 1 was a 2×3 factorial mixed design. The between-subjects independent variable was Stimulus type (pictures vs. words). Prime type (i.e., each participant saw targets primed with affordances, features, and non-associates) was a within-subject variable. The dependent variables for Experiment 1 were reaction time (defined as the time between the start of stimulus presentation to a button-press response) and accuracy (correct categorization with respect to fitting into a shoebox over the total number of responses per cell). To analyze the results a 2 (Stimulus type: pictures vs.

words) × 3 (Prime type: affordance, features, non-associates) mixed ANOVA was conducted.

2.4 Procedure

Participants were randomly assigned to view the target object as either a word or picture (see Figure 1). Participants in the word categorization task viewed the primes (affordance, semantic, non-associated) and targets (objects) as words. The picture categorization task had participants view primes as words and targets as pictures of objects. Participants sat in front of a computer monitor, while stimuli were presented. The shoebox sat beside the computer monitor, and for the duration of the experiment, participants could look at the shoebox at any point during a trial. Participants head movements were not restricted, with the exception that participants were required to remain a fixed distance from the screen at approximately 50 cm. Participants were acclimated to the task by completing 6 practice trials. Practice trials were identical to experimental trials.

Each trial began with a fixation point (a '+' sign in the middle of the screen) for 1000 ms, followed by an inter-stimulus interval for 250 ms (Figure 1). Participants were then shown a prime associated with a target object. Participants were asked to decide if the presented prime could fit inside of a shoebox. If a prime was unable to be put inside of a box (i.e. sit), participants were instructed to respond no. Primes were shown until participants responded. A visual mask was then shown to participants for 1000 ms followed by an inter-stimulus interval for 250 ms. Target objects were then presented as either a word or picture depending on the assigned condition. Participants were asked to respond by deciding if the presented object could fit inside of a shoebox. Participants were able to view objects until they made their decision. Responses to primes and targets were made continuously so that participants were not alerted to the relationship between primes and targets, and therefore had no knowledge of whether a stimulus was a prime or a target. Participants were asked to complete a short demographic and debriefing questionnaire with questions related to participant expectations and opinions of the experiment. Questionnaire answers were used to improve the design of the Experiment or to address possible demand characteristic issues.

2.5 Data Analysis

All reaction times and accuracy data for Experiment 1 are based on an $N=48$ due to data loss related to problems with the E-Prime software. As a result, responses for 10 participants were not recorded.

2.6 Results

Table 1 shows means and standard deviations for reaction times and accuracy by Stimulus and Prime type. The average reaction time was computed based on trials that resulted in correct responses. A main effect of Prime type was found on reaction times $F(2,92)=3.194$, $p<.05$, $\eta_p^2= .07$ (see Figure 2). Objects primed with affordances were responded to significantly faster than objects primed with non-associates ($F(1,46)=5.27$, $p=.03$). No other comparisons were statistically significant. A main effect of Stimulus type was significant on accuracy $F(1,46)=9.465$, $p<.01$, $\eta_p^2= .17$ (see Figure 3), in which participants were more accurate for classifying pictures than words ($p<.01$). The Stimulus type by Prime type interaction was not significant for any of the dependent measures.

2.7 Discussion

Objects primed with affordances showed a priming effect for reaction times, compared to non-associated primes. Object primed with semantic primes did not show a priming effect compared to non-associated primes. Affordance primes provided an advantage for objects presented as pictures. This provides evidence that affordance perception is optimally processed through sensory experiences (i.e., the information available in photographs taken of real objects). This is also evident in the accuracy of responses for objects primed with affordances. This was not the case for objects presented as pictures, which showed equal accuracy for all prime types. One caveat for the accuracy of words (either prime or target) is that there is no guarantee that participants thought of the same sized object (i.e., the word ‘ball’ in the current experiment could be a tennis ball or a soccer ball). One possible reason for the failure to find an accuracy effect may be due to data loss, and consequently, due to low statistical power.

Experiment 1 demonstrated a clear benefit to affordance primes when the information was presented pictorially. What is the nature of the visual information and what are the limits on the amount of information necessary to sustain such performance? The goal of Experiment 2 was to manipulate the amount of visual information available to participants to try to answer this question. I reasoned that when presented visual information was degraded, affordance primes would produce superior (faster and more accurate) responses. The perception of affordances is an automatic process that should allow for participants to recognize objects quicker even when the object is presented as a low-quality image (i.e., blurred, with higher spatial frequencies removed).

CHAPTER III – Experiment 2

In Experiment 2, I sought to manipulate the amount and quality of visual information present in pictures. I predicted that affordance primes would produce faster responding to target objects compared to semantic and non-associate primes, even when visual information was of poor quality.

3.1 Participants

68 (57 females; M_{age}=19.4 years) from the University of Southern Mississippi participated for partial course credit. Participants were required to have normal or corrected-to-normal vision and have no motor problems. A total of 75 participants were gathered for this experiment, but 2 participants had to be excluded due to E-Prime 3.0 crashing during data collection. Another 5 participants were removed from analysis due to distractions.

3.2 Materials

Participants viewed the stimuli on a 30-inch color computer screen connected to a Windows 10 laptop. Responses (button presses) were performed on a gaming keyboard. The stimuli were presented and button presses (response time) were controlled by E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA). A shoebox was visible to participants throughout the experiment. Pictures were artificially blurred using the gaussian blur feature in Photoshop. This feature applied the Gaussian function ($G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$) by a user specified amount (x) to every pixel of an image. The software allows the user to set up a radius (measured in pixels) to determine how far should the filter search for dissimilar pixels to blur. Pictures degraded with the extreme blur were transformed with a gaussian blur of 15 pixels (radius of blur area). The pictures in the medium blur condition were transformed with a gaussian blur of 7.5 pixels. For examples of stimuli se*e* Figure 4.

3.3 Design

Experiment 2 was a mixed factorial design. Participants were presented with 81 unique objects. Participants never saw the same object twice. The independent variables for Experiment 2 were Prime type (affordance, semantic, non-associate) and Image Quality (clear, medium blur, extreme blur). The dependent variables were reaction time (i.e., time from stimulus presentation to response button press) and accuracy (correct/total). To analyze the data a 3 (Image Quality) × 3 (Prime type) mixed effects ANOVA was computed on reaction time and accuracy.

3.4 Procedure

Participants were randomly assigned to view target objects that are either very blurry, somewhat blurry, or clear (see Figure 5). The primes were always presented as words, just like in Experiment 1. All other procedures were identical to those in Experiment 1.

3.5 Results

Table 2 shows descriptive statistics for reaction times and accuracy. The average reaction time was computed based on trials that resulted in correct responses. Results showed a main effect of Prime type on reaction time $F(2,130)=3.10$, $p<.05$, $\eta_p^2= .05$ (see Figure 6). Post hoc analyses identified that objects primed with affordances were responded to faster than objects primed with non-associates ($F(1,65)=4.53$, $p=.04$). There was a significant main effect of Prime type on accuracy, $F(2,130)=4.54$, $p=.012$, $\eta_p^2= .07$ (see Figure 7). Objects primed with affordances were categorized more accurately than objects primed with non-associates ($F(2,130)=10.63$, $p<.01$). There was also a significant effect of Image Quality on accuracy $F(2,65)=4.63$, $p=.01$, $\eta_p^2= .12$. Participants were more accurate when the image quality was clear compared to the maximum blur ($p<.01$).

3.6 Discussion

Results for Experiment 2 showed a significant priming effect for affordances. Objects primed with affordances were responded to faster than objects primed with non-associates collapsed across image quality, replicating the reaction time results from Experiment 1. The accuracy results from Experiment 2 show that objects primed with affordances were responded to more accurately than objects primed with non-associates.

The image quality manipulation did not significantly change the way primes and targets were responded to in terms of response time. A possible reason for the manipulation failure may have been due to the stimuli itself. Specifically, blurred images were presented as discrete static images. The perception of affordances is based on information patterns that embody changes in stimulus arrays (Gibson, 2014). Information emerges through changes in the optic array, which generates optic flow (Gibson, 1950; Koenderink, 1986). Because optic flow contains dynamic patterns over time, perception is dynamic and not based on perceiving a series of static snapshots of stimulus arrays. Therefore, the goal of Experiment 3 was to manipulate the amount of information given to participants through dynamically changing stimuli (an image that gradually shows more object features). I predicted that affordance primes would allow participants to respond to target objects at higher levels of blur faster than other primes (semantic and non-associated).

CHAPTER IV – Experiment 3

Experiment 2 showed a significant priming effect of affordance on reaction time and accuracy. To get a more accurate measure of the amount of information needed by participants to make the categorization decision I used a continuous measure of image blur. In Experiment 3 objects were fully blurred and gradually revealed more features to participants. Participants were asked to respond as soon as they recognized the objects. This could, in principle, provide a better measure of the amount of information needed for perceiving affordances, but it should not necessarily benefit object recognition. This prediction is also consistent with Gibson's conjecture that information that specifies perception is dynamic, not static.

4.1 Participants

44 (36 females; M_{age}=20.69 years) from the University of Southern Mississippi participated for partial course credit. Participants were required to have normal or corrected-to-normal vision and have no motor problems.

4.2 Materials

Participants viewed the stimuli on a 30-inch color screen connected to a Windows 10 laptop. Responses (button presses) were done on a gaming keyboard. The stimuli were presented and button presses (response time) were controlled by E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA). A shoebox was visible to participants throughout the experiment. Photographs used in Experiment 3 were altered in Photoshop. Image transitions were created by reducing gaussian blur from 25 px to 0 px over a 10 second period. Example of stimuli are shown in Figure 8.

4.3 Design

Experiment 3 employed a within-subject design. Participants viewed primes (words) and objects (pictures). The independent variable for Experiment 3 was Prime Type (affordance, semantic feature, non-associates). Reaction times and accuracy were used as dependent variables. To analyze the data a within-subjects repeated measures ANOVA was conducted on reaction times using Prime type as the independent variable with 3 levels (affordance, semantic, non-associate). A separate ANOVA was conducted on accuracy. Percent blur was not analyzed due to its perfect correlation with reaction time.

4.4 Procedure

Procedures were identical to those in Experiment 1 except for target stimuli (see Figure 9). For Experiment 3, target objects were presented as a completely blurred image that would 'fade in' to a clear image without any blur. The fade-in started at 100% blur (completely black screen) and gradually became a completely clear (0% blur) picture in 10 seconds. The speed of the fading in from a completely blurry image to a completely clear image was kept constant. Participants were asked to make their responses as soon as they were able to make their decision.

4.5 Results

Table 3 shows the means and standard deviations for reaction times and accuracy. The average reaction time was computed based on trials that resulted in correct responses. There was a marginally significant effect of Prime type on reaction time $F(2, 86)=2.96$, $p=.06$, $\eta_p^2=.06$ (see Figure 10). This marginal effect was carried by the apparent priming effect, i.e. the difference between semantic and non-associate prime trials (based on LSD-pairwise comparison, p=.03). The difference between affordance primes and non-associate primes was approaching significance (LSD comparison, p=.06). There was no main effect for Prime type on accuracy $F(2, 88)=0.54$, $p=.58$, $\eta_p^2=.01$ (see Figure 11).

CHAPTER V – Discussion Section

One of the goals of this research was to clarify the puzzling findings from Surber et al. (2018) showing that affordance primes inhibited responding to target objects (words). In that study the task was to judge abstractness versus concreteness of the target object. I reasoned that neither the stimuli (words) nor the task were not favorable to affordance perception due to being outside the domain of perceptual processing. It is plausible to assume that affordances are optimally perceived through sensory experiences (Experiment 1), and not via linguistic or abstract semantic processes. This means that perceptual information should be necessary to facilitate responding to target objects primed with affordances (Chainay & Humphreys, 2002). Specifically, affordance perception may not be activated by the abstract nature of words. I tested this hypothesis by using pictures as target stimuli.

Experiments 1 and 2 showed that participants were able to respond to target objects quicker and more accurately when they were primed with an associated affordance. This implies that affordances are processed differently than regular semantic features. Specifically, affordances seem better suited for visual stimuli, while semantic features are better suited for linguistic stimuli. This is supported by Glenberg's (1997) theory of embodied memory. Glenberg's theory is founded on the idea that memory and cognition guide perception and action. This means that the way that I process our environments is based on the relationship between what our bodies are capable of and the ways the environment constrains behavior. He further theorized that our memories are not formed by association in the traditional manner, but rather through patterns of actions connecting one idea to another. This could explain why affordance primes did not work with linguistic stimuli. Because language does not afford behavior in the same way that tangible stimuli do (i.e. actual environment/objects) any associations between affordances and linguistic information is weak. This also helps explain why a more perceptually relevant stimulus such as a picture was needed to facilitate affordance priming.

Carter, Hough, Stuart, and Rastatter (2011) found that the longer the inter-stimulus interval between trials the weaker the priming effects. This could explain the non-significant effects for Experiment 3. Specifically, because average reaction times were around 8 seconds, priming effects were weakened by the time participants responded to targets. To investigate this, confound a future study should be conducted applying the experimental manipulation from Experiment 3 using a shorter fade-in timeline. Participants would view targets that fade in from 100% blur to 0% blur in 5 seconds. Participants would be given a response deadline of 1.5 seconds, before the object disappears. This is comparable to average response times obtained in Experiments 1 and 2. Participants would still be able to respond after the object disappears but would only have a limited time to view the object. This should improve the strength of the priming effect.

Another future goal would be to create a stimulus that is more ecologically valid than linguistic information. Language may be too abstract to evoke the information necessary for affordance perception processes. The current series of experiments have shown that pictures of objects are sufficient to stimulate affordance perception; however, pictures do not provide information that can only be accessed through a dynamic perceptual stimulus such as real-world objects moving in space in the context of a behaviorally meaningful task. Real-world objects are better remembered (Snow et al.,

2014) and processed differently (Snow et al, 2011) than pictures. This means that there is meaning lost when an object is photographed. An ultimate test of this observation is to design a real-world replication of Experiment 1, in which targets are presented as either pictures or the actual object involved in task-specific motion.

It is also not clear what the exact nature of information is, and how much information is necessary to perceive affordances. The literature on biological motion offers some suggestions on this problem. Movement patterns recorded of human activity using point light displays are sufficient to specify what said activity is (Johansson, 1873). For example, lights attached to joints of the body and recorded as a person performs an action uniquely identify whether a person is walking, running, or doing some other activity. The information is dynamic, complex, and can typically be perceived over time as the pattern changes (Johansson, 1975). Static snapshots of such visual patterns are hard to recognize, but as soon as they are set into motion, the correlated movement patterns reveal the dynamic activity that is performed. For example, limb motion during hammering creates a very different visual pattern than limb motion when one hits a tennis ball with a racquet. I can recognize these patterns of action accurately and are able to determine characteristics about the actor (i.e. gender) or the action from only the motion in a point light display (Runeson & Frykholm, 1983). Future studies should utilize stimuli created with point light displays. Adding or removing the number of visible points tracking movement might provide the ultimate answer to the questions that were raised in Experiment 3 about the richness of informational components necessary to support visual perception of affordances.

APPENDIX A – Tables

Table A.1 *Descriptive Statistics Experiment 1*

Reaction Times	M	SD	N
Affordances			
Pictures	1003.801	294.8411	30
Words	1174.34	291.8008	18
Semantic			
Pictures	1071.8460	342.97929	30
Words	1133.0476	288.46196	18
Non-associates			
Pictures	1107.2679	318.58831	30
Words	1193.3667	361.94400	18
Accuracy	M	SD	N
Affordances			
Pictures	0.892593	0.0655	30
Words	0.82716	0.087091	18
Semantic			
Pictures	0.891358	0.055817	30
Words	0.835391	0.134576	18
Non-associates			
Pictures	0.895062	0.045707	30
Words	0.855967	0.08416	18

Table 1. Descriptive statistics for Reaction Time (in milliseconds) and Accuracy (proportion of correct responses) in Experiment 1.

Table A.2 *Descriptive Statistics Experiment 2*

Reaction Times	M	SD	N
Affordances			
Clear	1091.757	218.2791	22
Medium Blur	1193.69	339.298	22
Maximum Blur	1375.656	533.807	24
Semantic			
Clear	1129.0878	256.71529	22
Medium Blur	1224.7903	338.13413	22
Maximum Blur	1349.7198	518.16203	24
Non-associates			
Clear	1154.0848	215.43036	22
Medium Blur	1271.3166	355.95045	22
Maximum Blur	1439.8024	562.87256	24
Accuracy	M	SD	N
Affordances			
Clear	0.868687	0.094064	22
Medium Blur	0.845118	0.083709	22
Maximum Blur	0.23642	0.077163	24
Semantic			
Clear	0.868687	0.098806	22
Medium Blur	0.824916	0.068752	22
Maximum Blur	0.787037	0.094742	24
Non-associates			
Clear	0.855219	0.089933	22
Medium Blur	0.782828	0.105561	22
Maximum Blur	0.796296	0.10187	24

Table 2. Descriptive statistics for Reaction Times and Accuracy in Experiment 2.

Table A.3 *Descriptive Statistics Experiment 3*

Reaction Times	M	SD	N
Affordance	8241.818	792.9379	44
Semantic	8247.905	931.6865	44
Non-associate	8410.489	954.2495	44
Accuracy	M	SD	N
Affordance	0.841975	0.082591	44
Semantic	0.85679	0.092289	44
Non-associate	0.85679	0.088142	44

Table 3. Descriptive statistics for Reaction Times and Accuracy in Experiment 3.

APPENDIX B – Figures

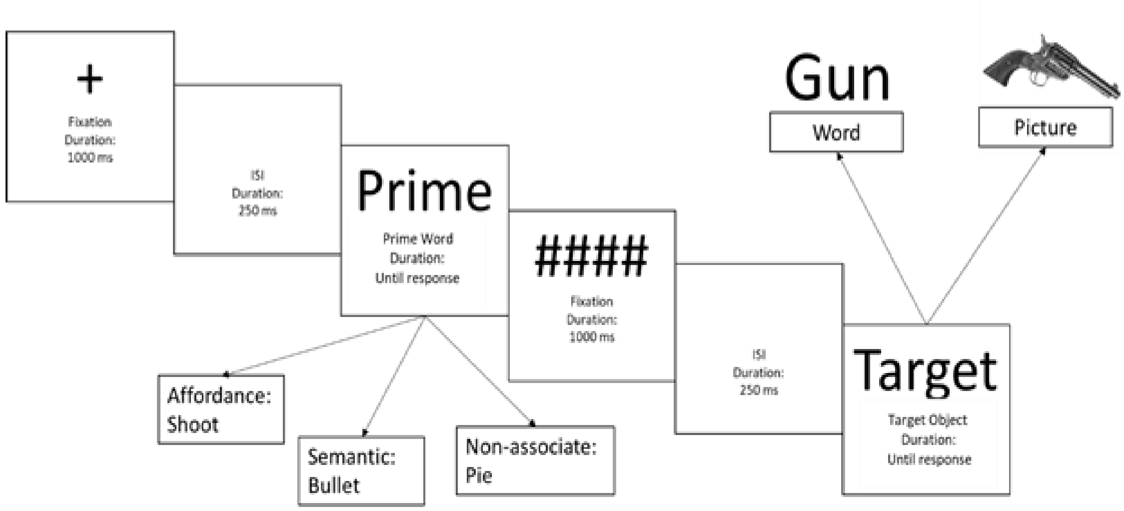

Figure B.1 *Timeline for Each Trial Sequence in Experiment 1*

Participants were presented with either an affordance, semantic, or non-associated prime, followed by the target object presented as either a word or picture.

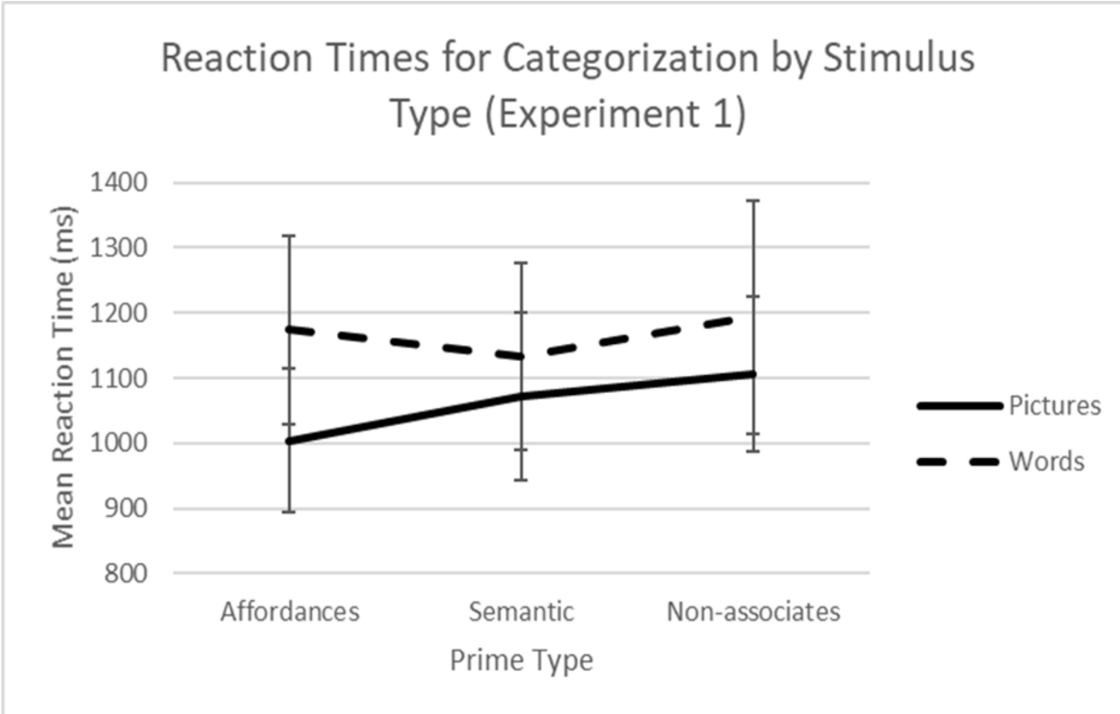

Figure B.2 *Reaction Times Experiment 1*

Mean reaction times for categorization decision by stimulus type. Error bars represent 95% confidence intervals.

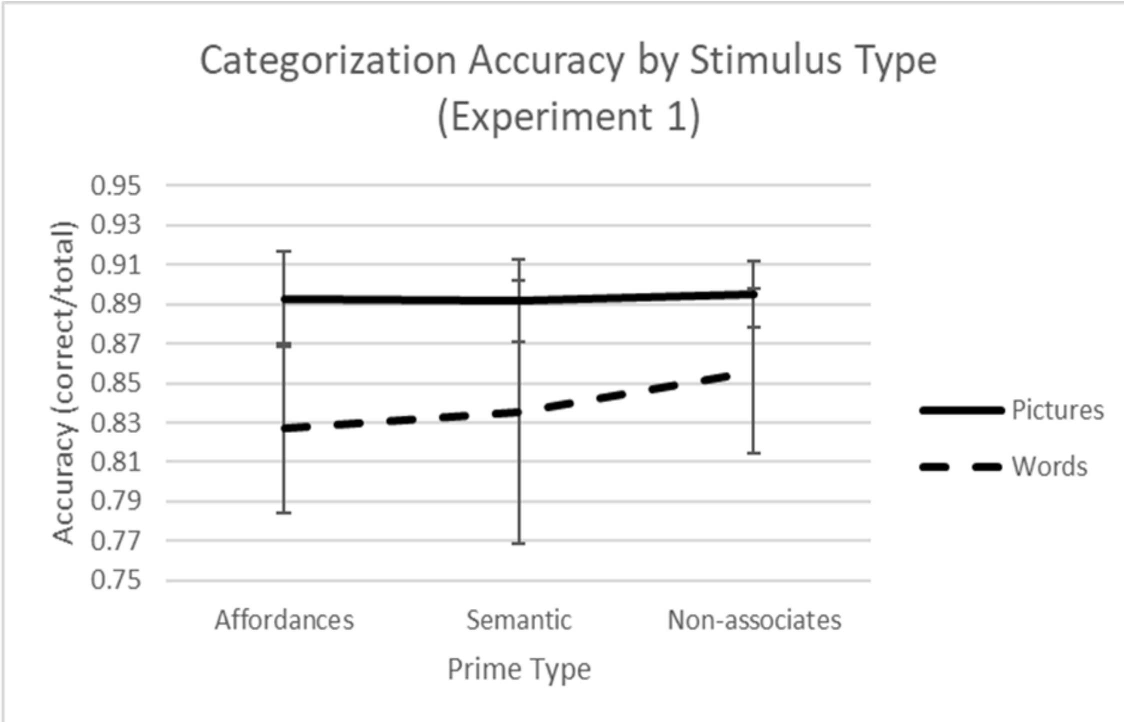

Figure B.3 *Accuracy Experiment 1*

Mean accuracy for categorization decision by stimulus type. Error bars represent 95% confidence intervals.

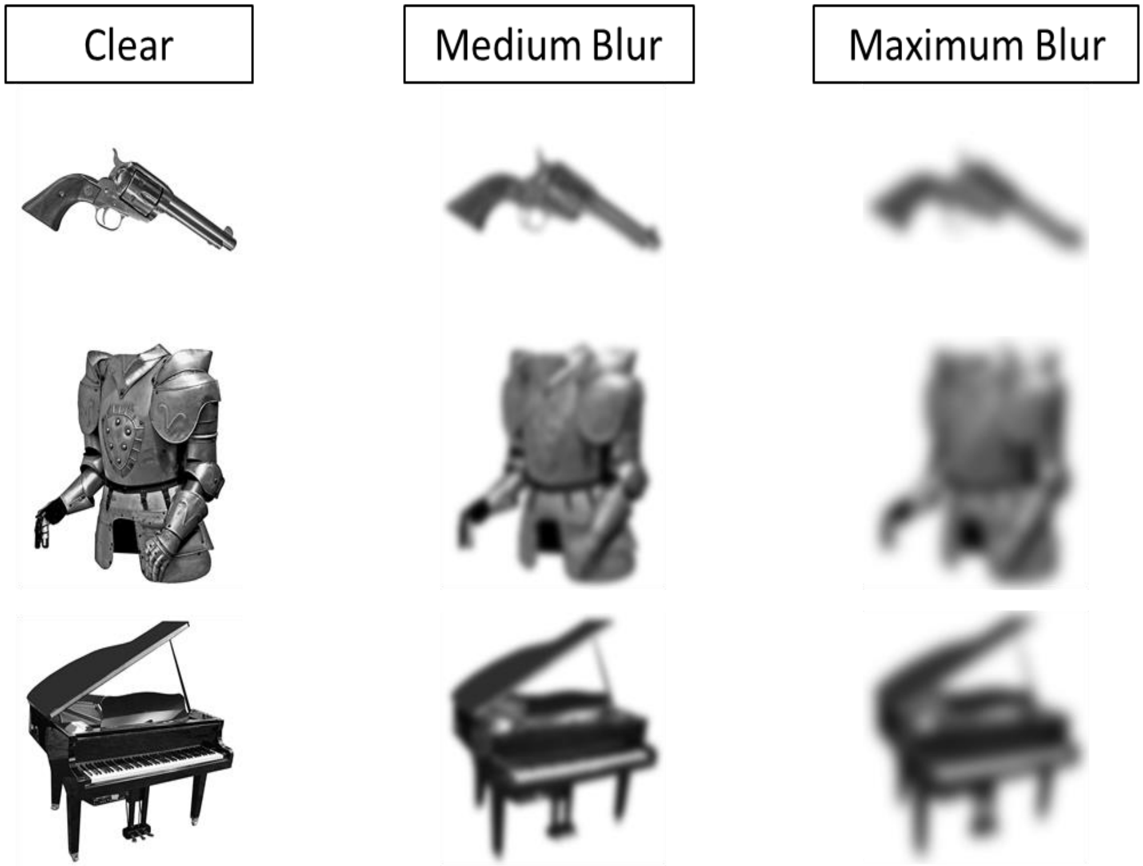

Figure B.4 *Examples of Stimuli for Experiment 2*

Objects were presented at the three different blur levels in Experiment 2. Participants saw all objects at only one of the three types of blur.

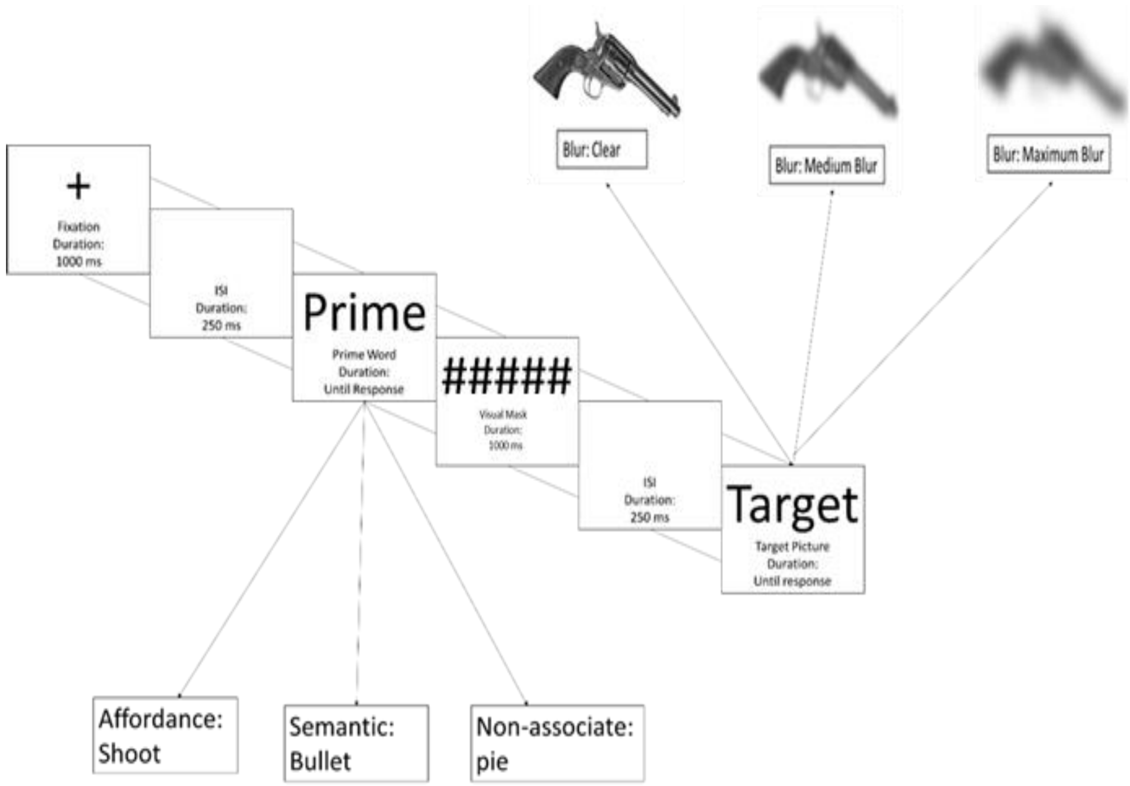

Figure B.5 *Timeline for Each Trial Sequence in Experiment 2*

Participants were presented with either an affordance-, semantic-, or non-associated prime. This was followed by a picture of the target stimulus object at one of the three image quality levels.

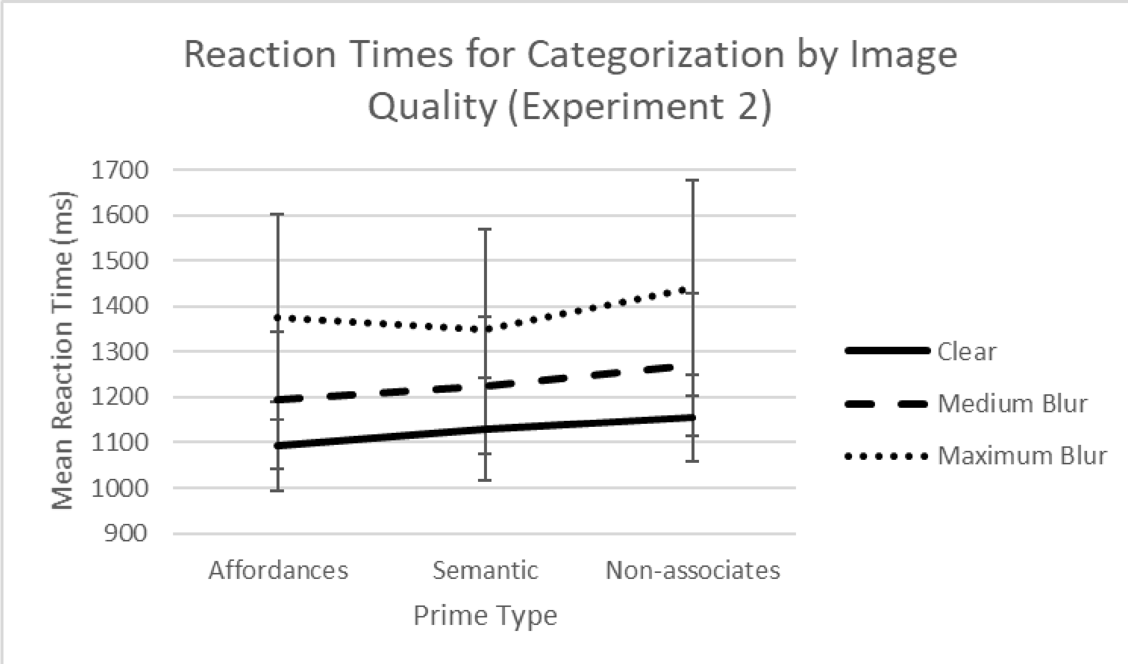

Figure B.6 *Reaction Times Experiment 2*

Mean reaction times for categorization decision by image quality in Experiment 2. Error bars represent 95% confidence intervals.

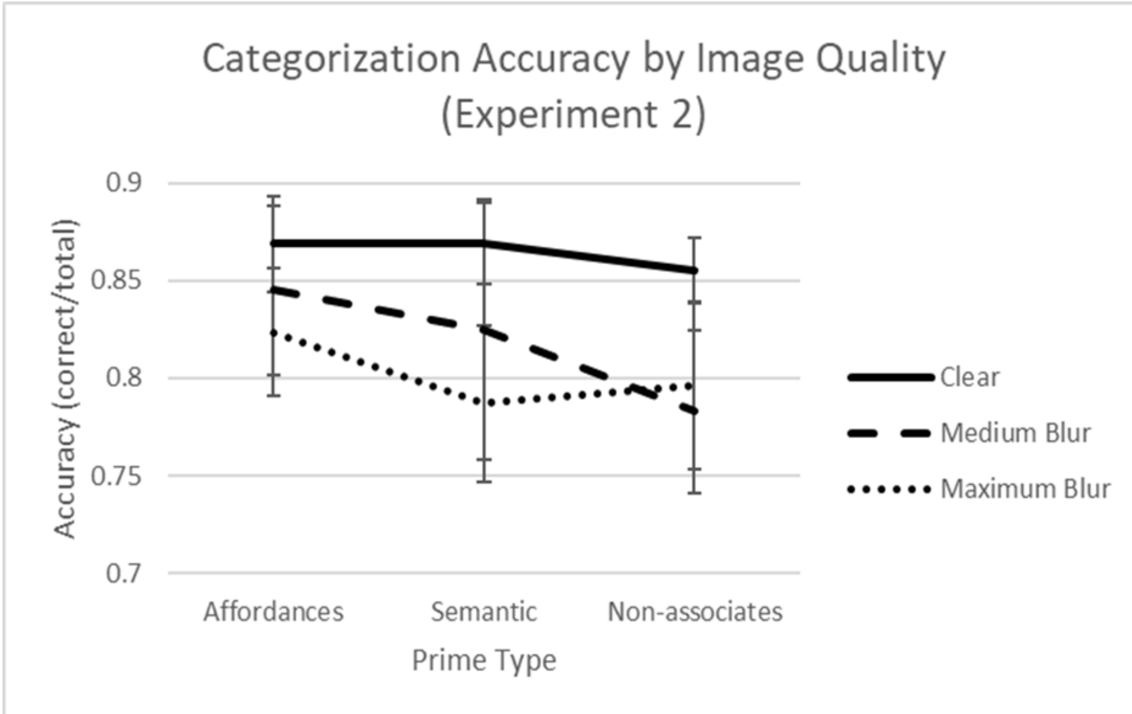

Figure B.7 *Accuracy Experiment 2*

Mean accuracy for categorization decision by image quality in Experiment 2. Error bars represent 95% confidence intervals.

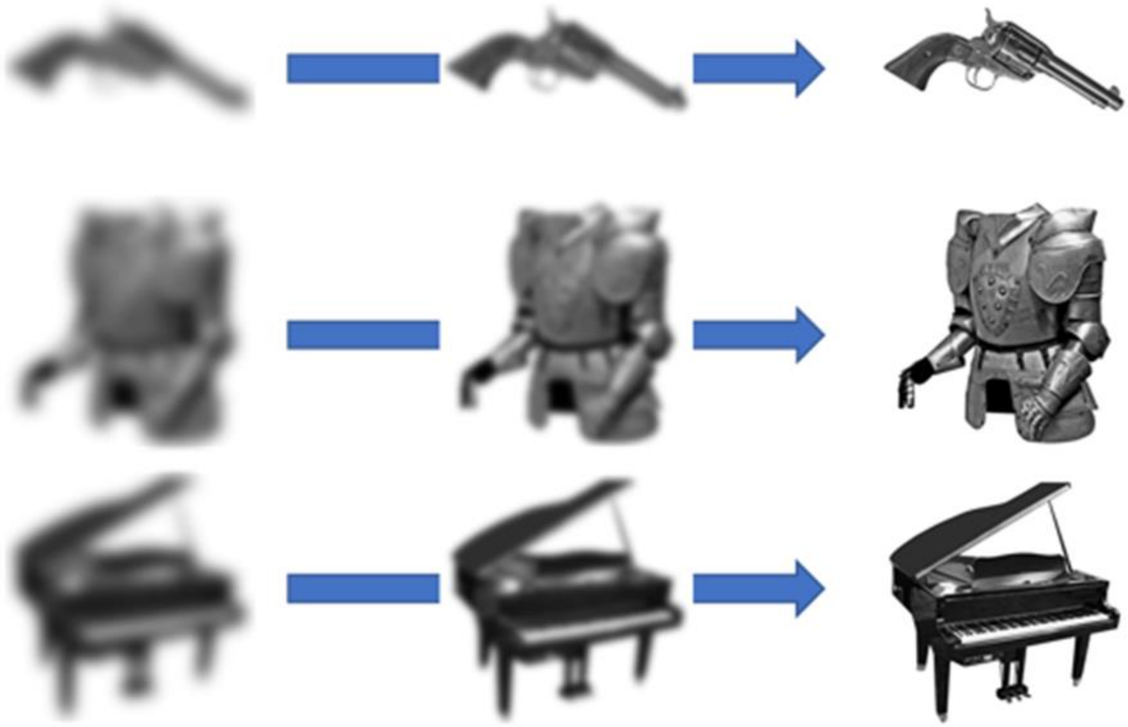

Figure B.8 *Examples of Stimuli for Experiment 3*

Objects as they transition from blurry (Gaussian blur of 25 pixel radius) to clear in Experiment 3. Participants responded when they recognized the object.

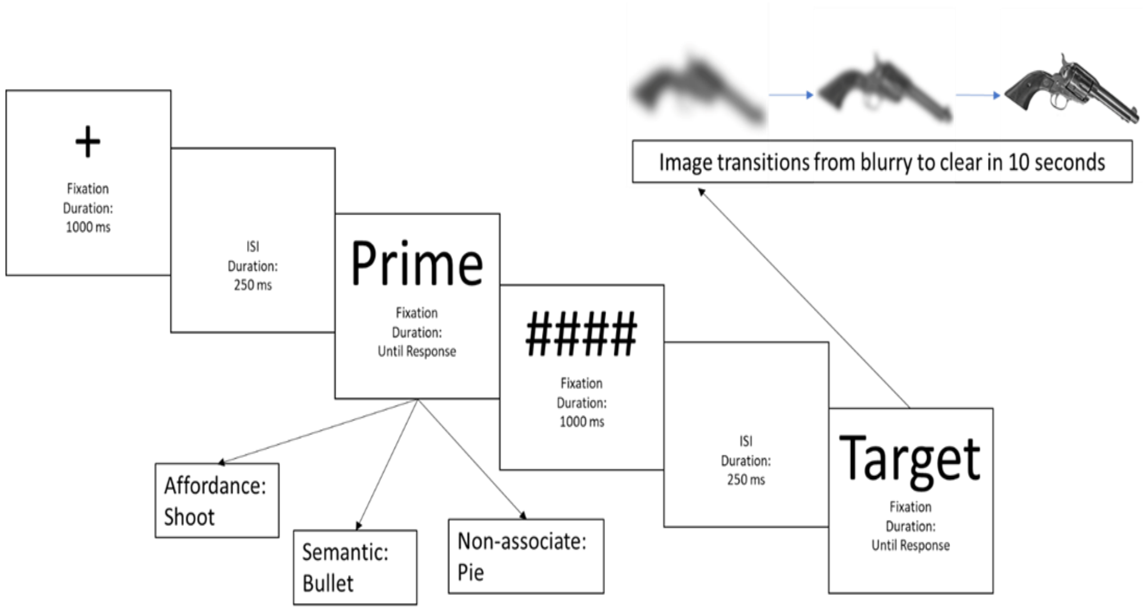

Figure B.9 *Timeline for Each Trial Sequence in Experiment 3*

Participants were presented with either an affordance, semantic, or non-associated prime.

Pictures of associated objects start out completely blurred and slowly become clear.

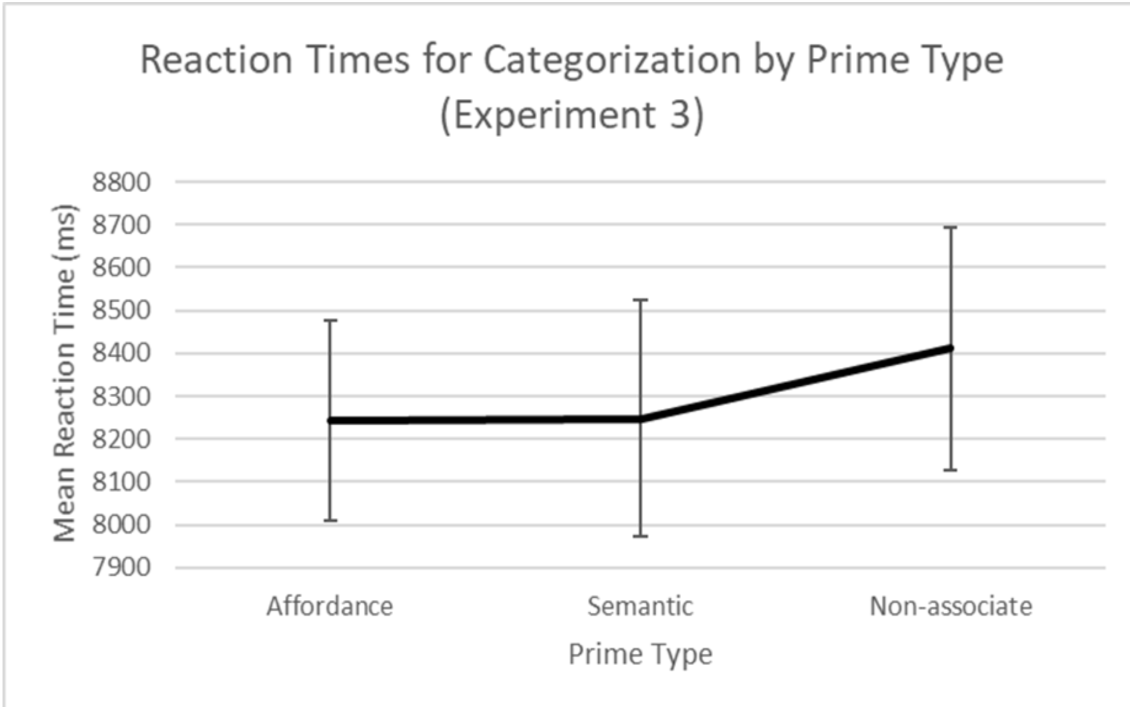

Figure B.10 *Reaction Times Experiment 3*

Mean reaction times for categorization decision for prime types in Experiment 3. Error bars represent 95% confidence intervals.

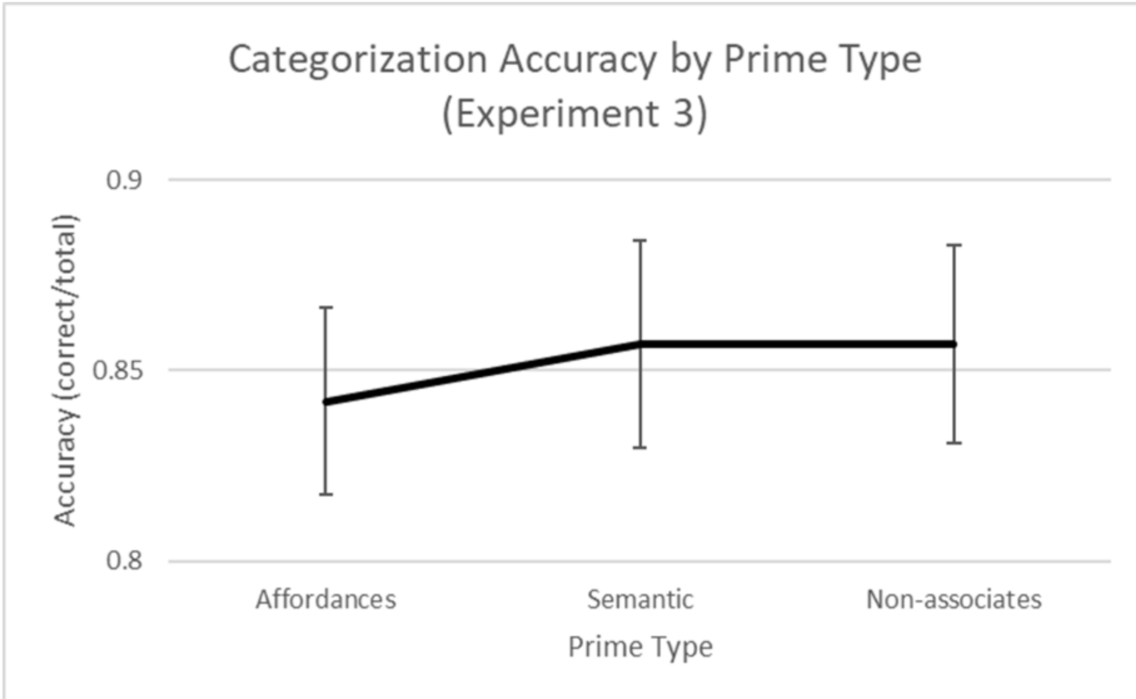

Figure B.11 *Accuracy Experiment 3*

Mean accuracy for categorization decision by for prime types. Error bars represent 95% confidence intervals.

APPENDIX C – IRB Approval Letter

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
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NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 18091111
PROJECT TITLE: Processing Speed for Action and Semantic Memory
PROJECT TYPE: New Project
RESEARCHER(S): Tyler Surber
COLLEGE/DIVISION: College of Education and Human Sciences
SCHOOL: Psychology
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 9/25/2018 to 9/25/2019

Edward L. Goshorn, Ph.D.
Institutional Review Board

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